Influence of Connected Health Interventions for Adherence to Cardiovascular Disease Prevention: A Scoping Review

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Abstract

Background Recent health care developments include connected health interventions to improve chronic disease management and/or promote actions reducing aggravating risk factors for conditions such as cardiovascular diseases. Adherence is one of the main challenges for ensuring the correct use of connected health interventions over time.

Objective This scoping review deals with the connected health interventions used in interventional studies, describing the ways in which these interventions and their functions effectively help patients to deal with cardiovascular risk factors over time, in their own environments. The objective is to acquire knowledge and highlight current trends in this field, which is currently both productive and immature.

Methods A structured literature review was constructed from Medline-indexed journals in PubMed. We established inclusion criteria relating to three dimensions (cardiovascular risk factors, connected health interventions, and level of adherence). Our initial search yielded 98 articles; 78 were retained after screening on the basis of title and abstract, 49 articles underwent full-text screening, and 24 were finally retained for the analysis, according to preestablished inclusion criteria. We excluded studies of invasive interventions and studies not dealing with digital health. We extracted a description of the connected health interventions from data for the population or end users.

Results We performed a synthetic analysis of outcomes, based on the distribution of bibliometrics, and identified several connected health interventions and main characteristics affecting adherence. Our analysis focused on three types of user action: to read, to do, and to connect. Finally, we extracted current trends in characteristics: connect, adherence, and influence.

Conclusion Connected health interventions for prevention are unlikely to affect outcomes significantly unless other characteristics and user preferences are considered. Future studies should aim to determine which connected health design combinations are the most effective for supporting long-term changes in behavior and for preventing cardiovascular disease risks.

Keywords
- cardiovascular disease
- adherence
- connected health intervention

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Background and Significance

According to the World Health Organization, cardiovascular diseases (CVDs) are the leading cause of death worldwide. Indeed, the last decade has seen an increase of at least 60% in the number of deaths related to CVDs from 36 million people worldwide.[1] Nondrug interventions (NDIs) are increasingly studied as a way of motivating users to change their behavior in the context of chronic disease prevention. The Collaborative University Platform for Evaluating Health Prevention and Supportive Care Programs proposes open-access resources for validating and monitoring NDIs of five different types: nutritional health interventions, psychological health interventions, physical health interventions, digital health interventions, and other health interventions.[2] Most of these interventions deliver population-based recommendations that are available at institutional level. Nevertheless, there is a growing view—fueled by e-health and the silver economy— that connected health interventions are NDIs that would probably be beneficial for patients with chronic diseases, including those with well-known risk factors for CVDs, through self-monitoring, reminders, enhanced communication, and interaction with health care professionals.

Over the last two decades, multiple definitions of the term "e-health" have been put forward. We define "e-health" as the use of communication technologies for the remote monitoring of health status data for patients. This relatively recent health care practice provides opportunities for the interventions to improve chronic disease management and/or to promote actions reducing aggravating risk factors for conditions such as CVDs. For instance, patients use connected devices, such as connected scales and connected blood pressure monitors, for self-monitoring to assess their own physiological status, signs, or symptoms.[3]

In addition to monitoring, e-health provides opportunities for using short text messaging (e.g., SMS), follow-up surveys, and other mobile phone-based methods (collectively often called "m-health") to encourage patients to engage in their own health care. Almost a decade ago, it was estimated that more than 6 billion people worldwide had access to mobile phones,[4] and the availability of these devices has continued to increase. These possibilities have been greeted with considerable enthusiasm—thanks to the transportability, relatively low cost, and widespread use of this technology.[5] In this study, we include digital methods of collective monitoring, such as focus groups or online user challenges, within the umbrella term "connected health interventions." Such interventions have already proved useful for managing CVD risk factors, helping people to stop smoking, reducing sugar consumption, and increasing daily levels of physical exercise.

Adherence is one of the main challenges in connected health interventions. Adherence can be defined as the persistence over time of correct use of the connected health tool or application. It is, therefore, of the utmost importance to identify specific interventions for helping patients to achieve effective self-management in chronic diseases. For instance, a given intervention may enable them to monitor their diabetes or arterial hypertension over time, with a view to preventing risk factors for CVDs.

Objective

We performed a scoping review of the connected health interventions used in interventional studies, describing the ways in which these interventions and their functions effectively help patients to deal with cardiovascular risk factors over time, in their own environments. The objective was to acquire knowledge and to highlight current trends in this field emerging, but productive field. We focus in this scoping review on the three major dimensions of this objective:

- Which well-known cardiovascular risk factors are efficiently addressed, individually or in combination, by connected health interventions?
- Which types of connected health interventions appear to be the most developed in interventional studies?
- To what extent is adherence to these interventions over time considered in these interventional studies?

This paper is organized as follows. We first review interventional studies on this theme in accordance with scoping methodology. We then highlight the elements identified in these papers as influencing adherence to connected health interventions for preventing CVD risk, according to the three dimensions presented above (cardiovascular risk factors, connected health interventions, and adherence). We then describe the results of several connected health interventions for increasing motivation and adherence. In the final section, we compare our findings with those of similar studies and identify current challenges and future opportunities.

Methods

The scoping review method is a useful way of dealing with the ever-increasing number of evidence synthesis approaches. Scoping reviews and systematic reviews are performed for different purposes. A scoping review tends to have a broader research question than systematic reviews, with the inclusion/exclusion criteria defined later in the process and with trends as the principal findings, rather than the synthesized and aggregated findings of systematic reviews. In the emerging field of connected health interventions for the prevention of CVDs, a scoping review is an appropriate method for screening existing knowledge and exploring the available evidence and gaps in our knowledge within this research area.[6] We used a scoping review search strategy to search for original reports of studies evaluating connected health interventions with rating scales or qualitative questionnaires in MEDLINE (medical literature analysis and retrieval system online), using PubMed.

In this section, we present the following steps: query construction with Medical Subject Headings (MeSH) resources and literature search strategy.

Query Construction with Medical Subject Headings Resources

We used a medical bibliographic HeTOP (Health Terminology/Ontology Portal) query builder to build complex bibliographic queries by combining medical terms from MeSH. The building strategy for each query was discussed, tested, and refined

internally by the authors, and was also reviewed by an external reference librarian. We included the three dimensions considered in this query. ►Supplementary Table S1 (available in the online version): structure of search queries.

#1:mhealth

((mhealth[tw] OR mobile health[tw] OR telehealth[tw] OR eHealth[tw] AND electronic health[tw] OR digital health [tw] OR mobile app*[tw] OR mobile phone*[tw] OR cell phone*[tw] AND cellular phone*[tw] OR smartphone*[tw] OR tablet*[tw] OR smart phone*[tw] OR iPhone* OR iPad* OR android OR handheld*[tw] OR phone call*[tw] OR short messag*[tw] OR sms[tw] OR message*[tw] OR mms[tw] OR text messag*[tw] OR telemedicine[mh] OR mobile applications[mh] OR reminder systems[mh]))

#2: Cardiovascular disease

(cardiovascular[tw] OR cardia*[tw] OR heart*[tw] OR coronary*[tw] OR myocard*[tw] OR angina*[tw] OR infarct*[tw] OR ischem*[tw] OR arrhythmia*[tw] OR hyperten*[tw] OR hyperlipidemia[tw] OR heart failure[tw] OR stroke*[tw] OR cerebrovasc*[tw] OR peripheral arterial disease*[tw] OR peripheral vascular disease*[tw] OR peripheral artery disease[tw] OR Cardiovascular Diseases[mh] OR Acute Coronary Syndrome[mh] OR Stroke[mh**]))**

#3: Adherence to drugs and NDI treatments

(adheren*[tw] OR medication adherence[mh]))

Literature Search Strategy

We performed a systematic search of the literature covering a 5-year period, from September 2015 to February 2019, on PubMed. We chose to focus on this 5-year period as the connected health domain has only recently emerged and is developing rapidly, with the technology used becoming obsolete equally rapidly. The data extracted were reported in BibReview, a bibliographic software tool developed in the context of the yearbook of medical informatics.[7] ►Fig. 1 shows a screenshot of the BibReview user interface from our initial search, which yielded 98 articles in PubMed.

Results

Here, we illustrate the different situations or contexts identified for the three dimensions.

Bibliometrics

Articles were processed for inclusion according to the steps presented in ►Fig. 2.

The flowchart provides a detailed description of the selection process and the reasons for excluding papers:

- Identification: A total of 20 articles were duplicates. We retained only one instance of each.
- Screening: A total of 78 articles were screened on the basis of their title and abstract. Articles were excluded if no mention was made of connected health interventions (1), or if they did not focus on the CVD setting (2).
- Eligibility: A total of 49 articles underwent full-text screening for eligibility. When it was not possible to decide whether a study should be included or excluded on the basis of the title and abstract alone, the full text was retrieved and reviewed by at least two people. In cases of

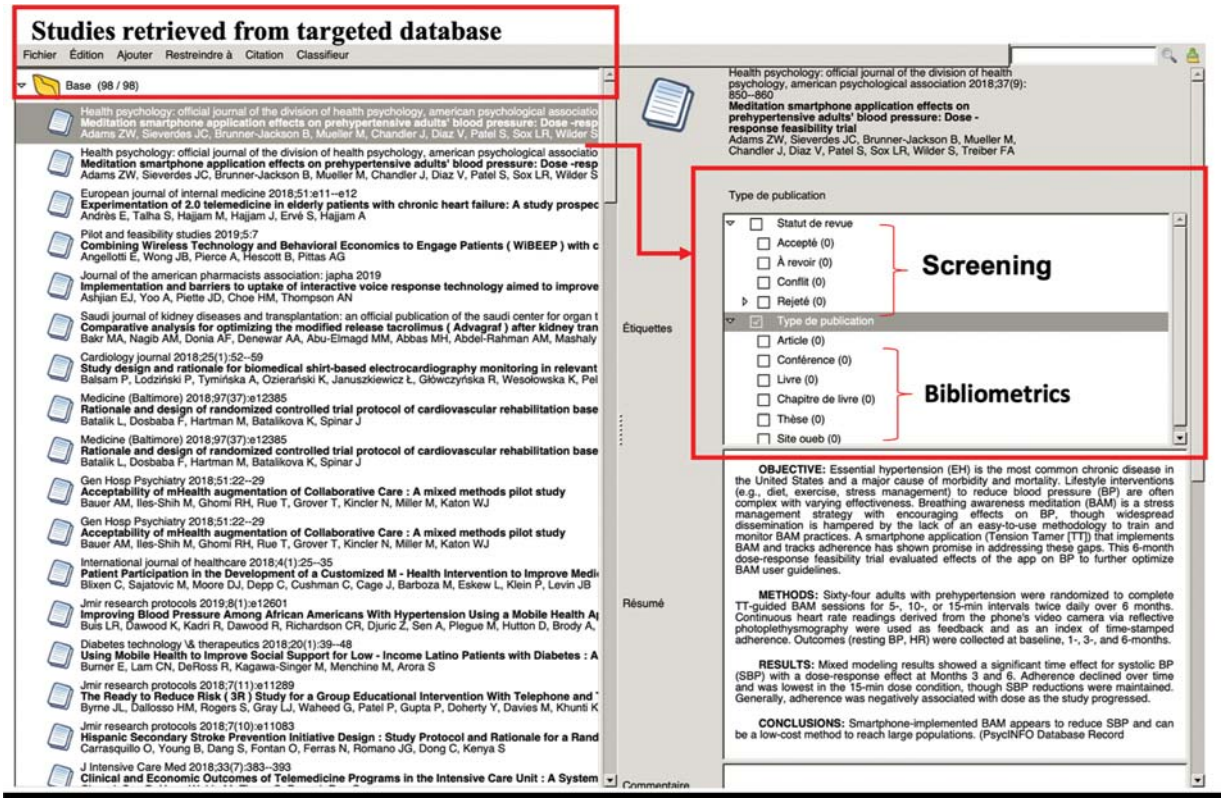

Fig. 1 BibReview screenshot.

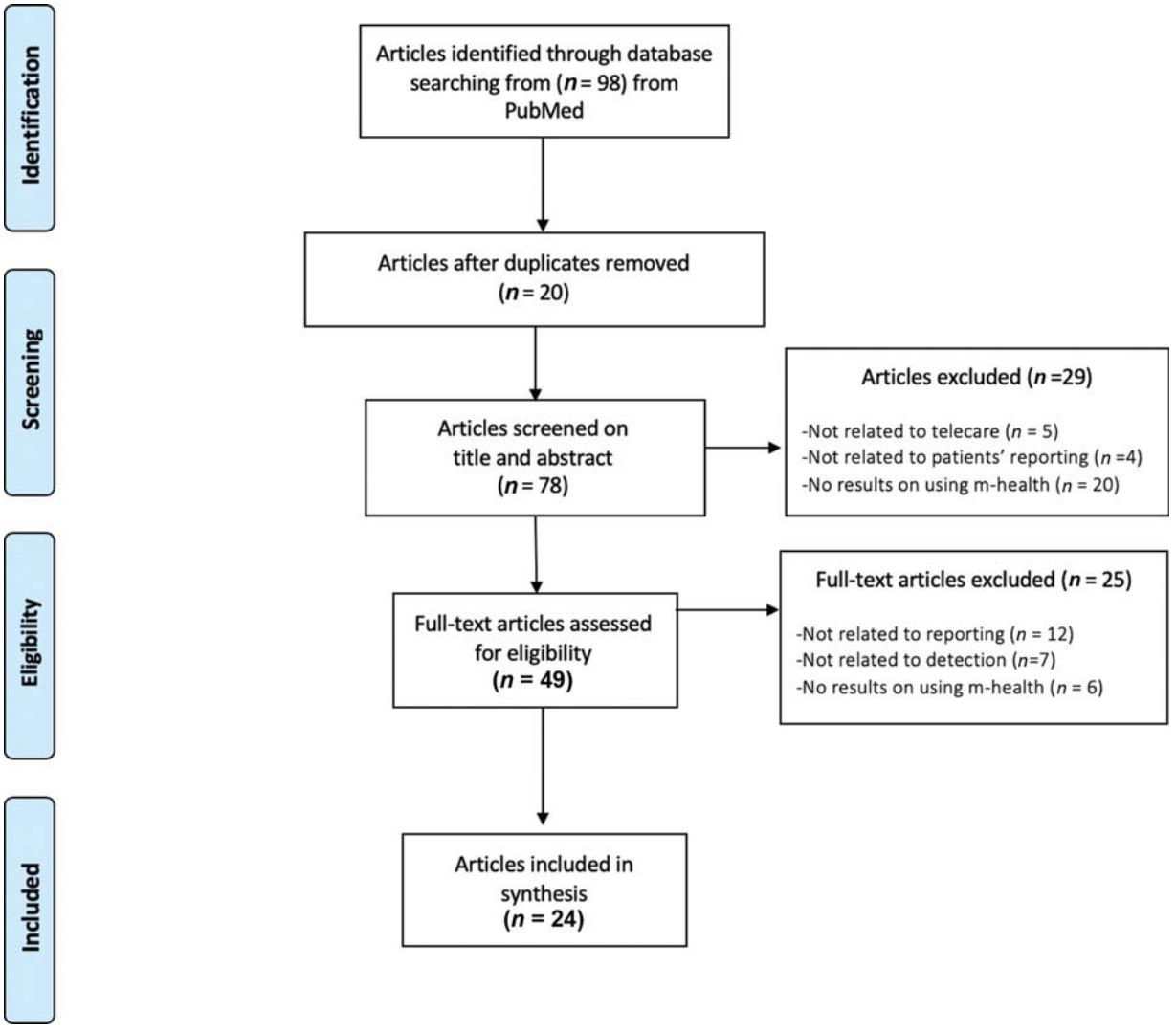

Fig. 2 Flow diagram for article inclusion.

disagreement between reviewers, a decision was taken after discussion between the reviewers.

- Included: A total of 24 articles were included in this review. Articles were included if they focused on health services for users and risk factors for CVDs, and if they had an outcome related to health behavior or presumed to be a consequence of health behavior (such as a dieting intervention).

The 24 articles are identified by a number[8–31] and the reference list can be found in ►**Supplementary Table S2** (available in the online version). The characteristics extracted from the 24 articles are shown in ►**Supplementary Tables S3–S5** (available in the online version). We used a method based on Laranjo's[32] reading grid to compare the selected articles. This reading grid contains several variables: study, author, year, risk factors, connected health intervention, total number of people, age, ethnic group, study duration, adherence, and function categories, as defined in the first meta-analysis on the influence of social networking sites on health behavior.[32] We detail below the three variables studied corresponding to the three dimensions for the analysis in our context:

- Risk factors: Clinical and behavioral risk factors. A recent study[33] proposed a predictive model for CVDs identifying different types of risk factor variables: nonmodifiable variables, behavioral variables, clinical risk factors, and interactions between them. In our review, the risk factor categories considered were: hypertension, dyslipidemia, type 2 diabetes, obesity, sleep disorders, stress, depression, alcohol consumption, smoking, food disorders, and sedentary behavior.
- Connected health interventions: Connected devices and approaches, as described above, acting on health behavior, such as SMS, surveys, focus groups, smartphone health applications, and solutions combining several aspects of connected health. These interventions have a considerable potential to convey recommendations or to influence sustainable changes in lifestyle over time.
- Adherence, which can be defined as the persistence over the time of correct use of the intervention, an intervention targeting a risk factor and including a "motivational"

function. Several criteria can be used to evaluate adherence: patient perception, acceptability of the technology and service, reliability of the information and communication technologies, patient motivation, social network, ease of use, and implementation in everyday life.

Risk Factors for Cardiovascular Diseases

Most of participants from the 24 studies included were adults. Nonmodifiable variables were always present but were coded in different ways. For instance, age was mostly categorized as "young" or "old," but some studies focused on specific populations, such as the "middle aged," individuals over or under the age of 65 years,[18] or exclusively young individuals.[26] In some studies, the population was restricted on the basis of ethnic origin, social status or education,[9] or to a particular ethnic group, such as African Americans and Vietnamese.[26]

►Fig. 3 shows the distribution of risk factors taken into account in the articles. Two articles[11,16] considered both clinical risk factors (hypertension, type 2 diabetes) and behavioral variables (diet and physical activity).

Four articles dealt with four or more risk factors, but most articles dealt with only one or two. Five articles included applications not focusing on cardiovascular risk factors but more generally on CVDs.[17,18,20,21,31] The risk factor "dyslipidemia" was considered in some articles.[11,12,16,23,27,29] Finally,

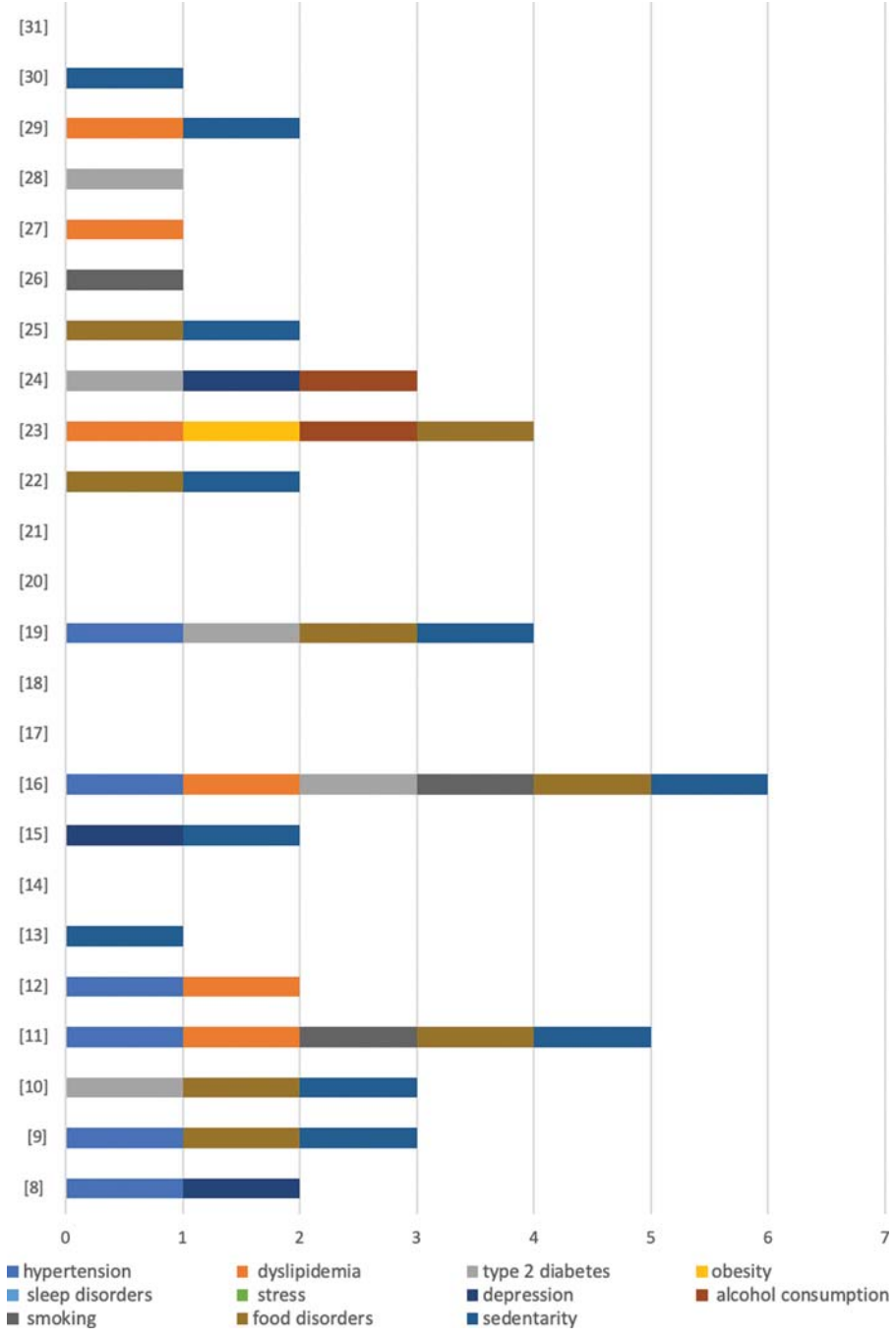

Fig. 3 Risk factors for cardiovascular diseases mentioned in the papers selected.

we noted that certain risk factors, such as "stress" and "sleep disorders," were not assessed in terms of connected health interventions and adherence to them. The most frequently mentioned risk factor was hypertension. The risk factor most frequently considered in isolation was sedentary lifestyle, and the most frequent combination of risk factors considered was a sedentary lifestyle + food-related disorders.

Connected Health Intervention

With the advent of highly pervasive new technologies (relating to the field of the Internet of Things in general), connected health has raised hopes for improving health status through the use of blood pressure monitors, pedometers, and other medical devices measuring vital signs and physiological status, for informative and preventive purposes.

►Fig. 4 shows the results for the three categories of connected health interventions taken into account in the articles. These categories concern three types of users' actions: (1) to read, read a message on a connected health intervention (on apps), (2) to do: set up actions such as user feedback, and (3) to connect: use application.

For instance, one study[25] investigated the effects of mobile messaging applications on knowledge about coronary artery disease. This study concluded that WhatsApp was an effective way to take action in health, increasing the knowledge of patients with coronary artery disease, and that messaging was an effective way of promoting a healthy lifestyle.

Another study[19] evaluated the feasibility and acceptability of the simultaneous application of wireless home blood pressure monitoring (as an example of "nudging") and approaches targeting pharmacological treatment and lifestyle habits in patients with cardiometabolic disease (type 2 diabetes and/or hypertension). The patients with cardiometabolic disease studied reported that lifestyle-targeting text messaging approaches were feasible and acceptable, and that the text messages were easy to understand (88%) and were sent at an

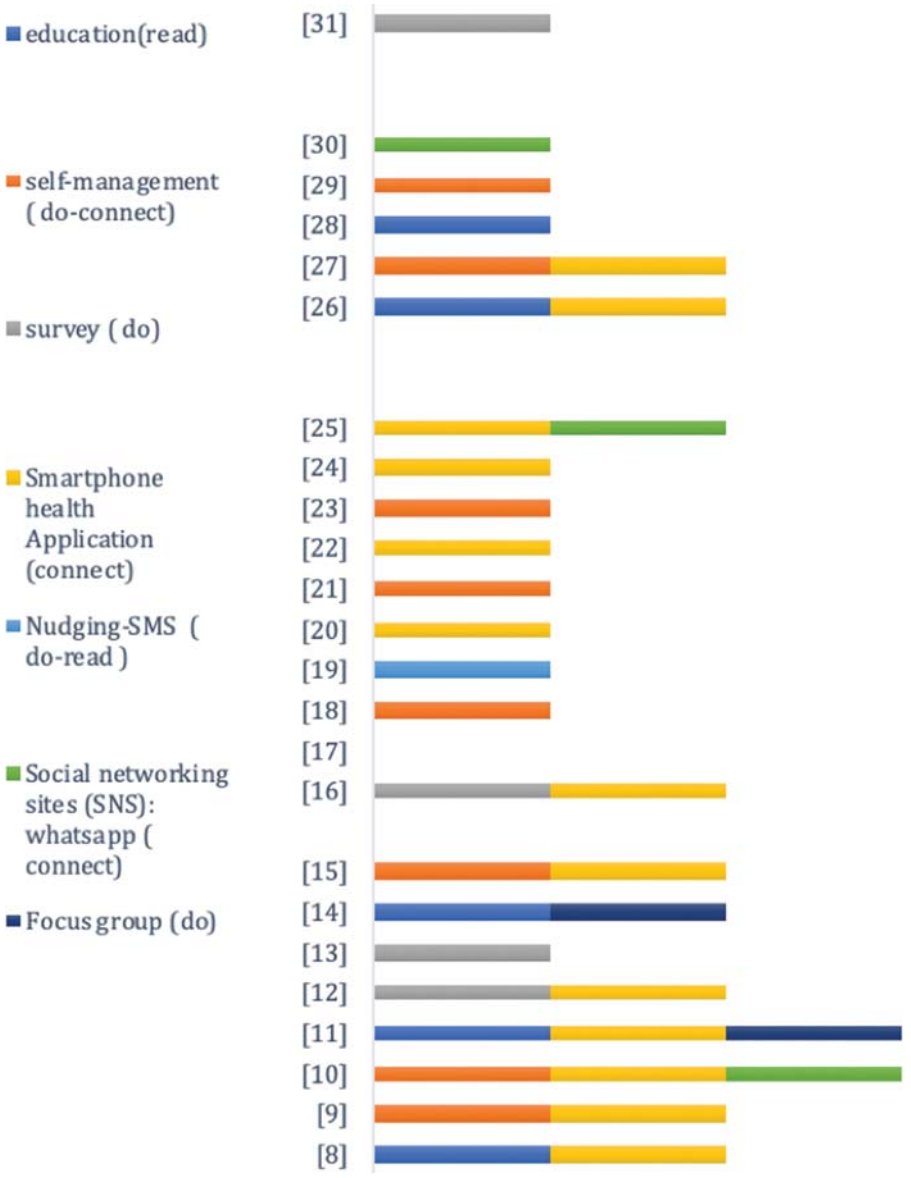

Fig. 4 Connected health interventions used in the selected papers.

appropriate frequency (71%), in appropriate language (88%). Most of the studies used "smartphone health applications (connect)"[8–12,15,16,19,20,22,24–27]. "Focus group" (do) and "Education" (read) were used together in two articles.[11,14] In one article,[11] a combination of Nudge-SMS (do-read), smartphone health application (connect) and focus group (do) interventions was studied. The intervention consisted of two group-training sessions based on telephones and text messaging, using recognized behavior-changing techniques.

Adherence

Adherence can be defined as the persistence over time of correct use of the intervention.

In the absence of a reference scale, we adopted a bottom-up approach to define a reading grid for adherence.

►Fig. 5 shows the outcomes for the various types of adherence considered in the articles. For instance, in one article,[11] the questionnaire used was the gold-standard questionnaire developed by Morisky, the eight-item Morisky drug adherence scale. Drug adherence is considered good for scores of at least 8, moderate for scores of 6 or 7, and poor for scores below 6.

Most of the articles reported positive effects on adherence, with values of "adherence >50%," shown as a blue line in ►Fig. 5. In six articles, "moderate adherence" (orange line) was achieved.[8,14,17,22–24] Five articles did not mention or evaluate adherence. These articles are indicated by gray lines as "adherence unknown" in ►Fig. 5.[12,15,16,25,26]

We provide a synthetic analysis of the outcomes described in this section in terms of the distribution of bibliometrics, connected health interventions and adherence.

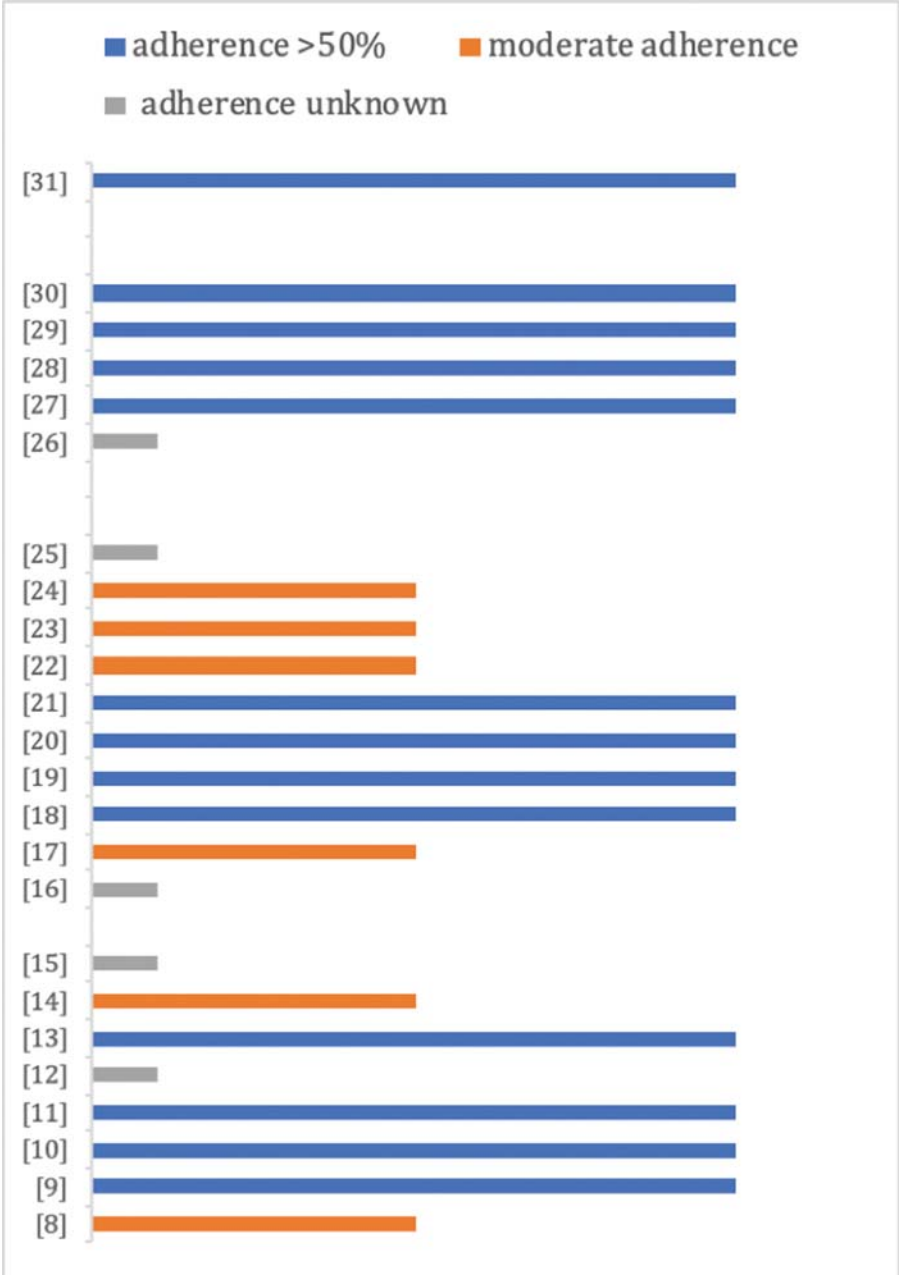

Fig. 5 Adherence evaluation from the selected papers.

Distribution of Outcomes

Bibliometrics Distribution

All 24 publications included in this review were published in 2018 or 2019, confirming the recent emergence of this research topic (►Fig. 6A). ►Fig. 6B shows the number of articles per type of article. For example, 14 of 24 articles were written by academics or researchers. The institutions to which the first authors were affiliated were mostly in the United States (8 of 24, 33.3%), the United Kingdom (5 of 24, 20.83%), and Australia (4 of 24, 16.6%; ►Fig. 6C).

Distribution of Connected Health Interventions

►Fig. 7 shows the distribution of connected health interventions. These connected health interventions included social networks (connect, 8%), self-management applications (do-connect, 29%), mobile applications (connect, 17%) surveys (do, 17%), nudge-SMS (do-read, 4%), and education (read, 25%), for various domains, including quality of life, health status, and activities of daily living. The studies included focused more on "do-connect" interventions (e.g., self-management applications, 29%) than on "do-read" interventions (e.g., nudge-SMS, 4%). Self-management "do-connect" interventions were the most frequent (29%).

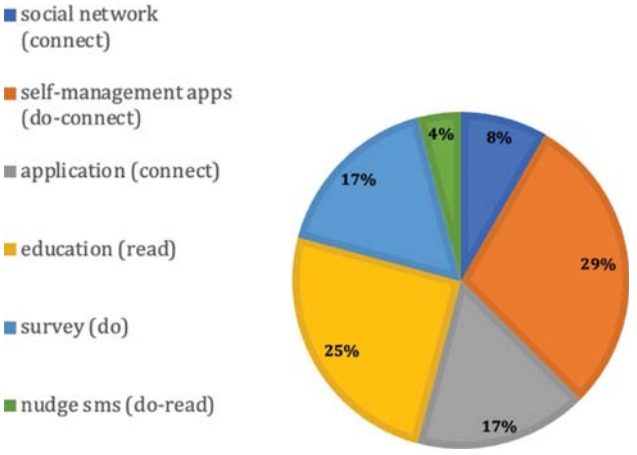

Fig. 7 Distribution of connected health interventions.

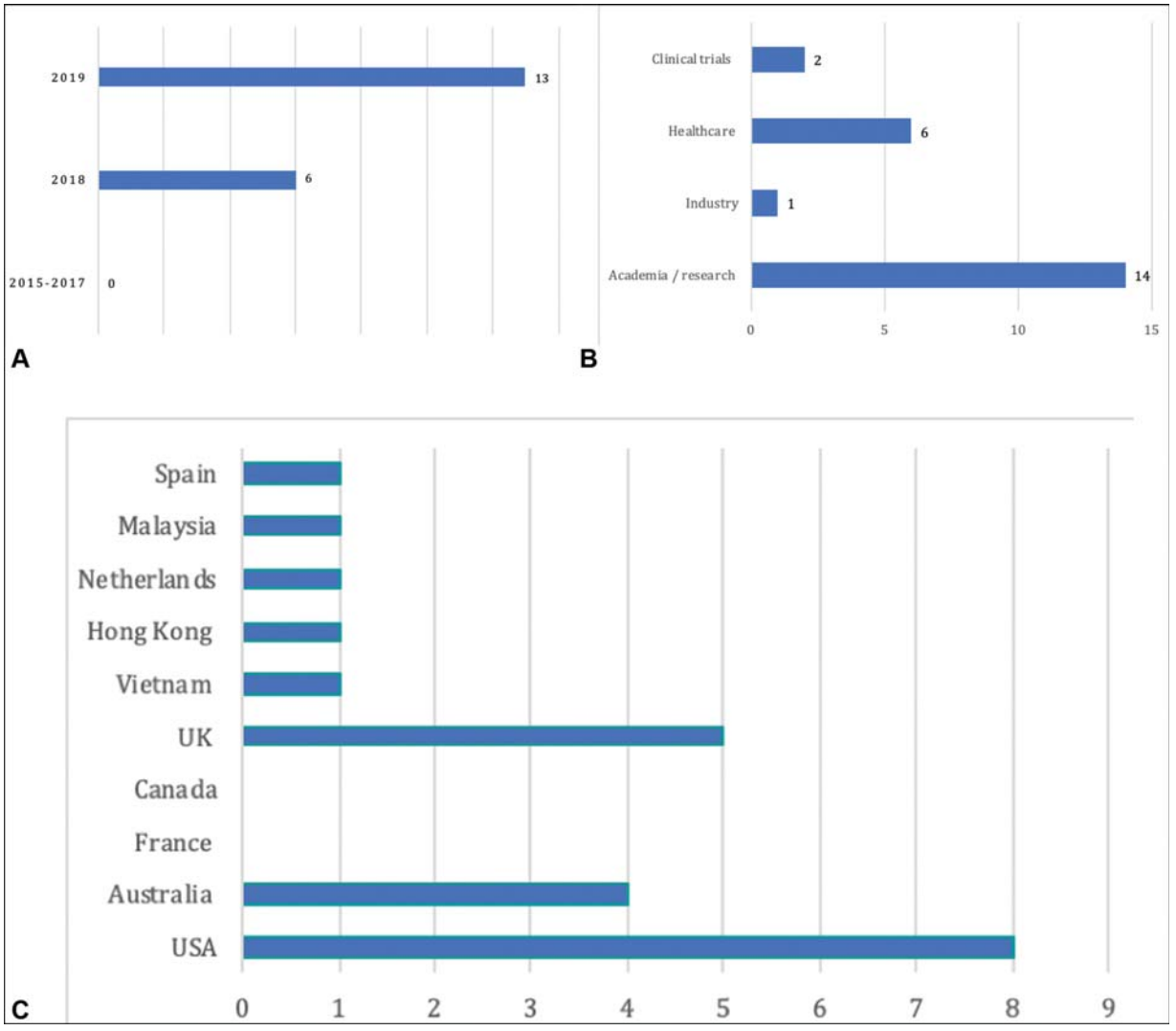

Fig. 6 Bibliometrics. (**A**) Distribution of the selected articles by year. (**B**) Number of articles per type of author. (**C**) Distribution of papers by country.

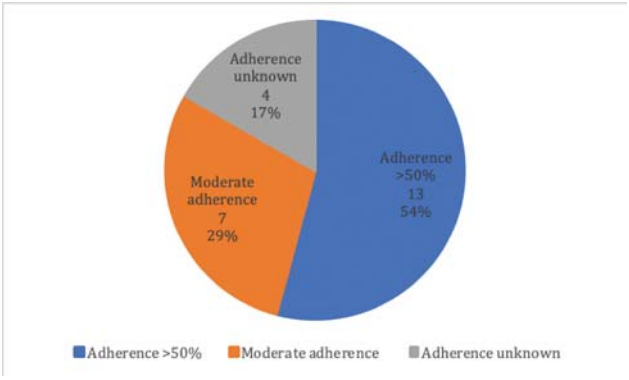

Fig. 8 Adherence distribution.

Adherence Distribution

The findings for adherence distribution are potentially interesting for the development of connected health approaches, but it is difficult to compare results across interventions due to differences in study design and reporting. ►**Fig. 8** shows the distribution of connected health interventions achieving various levels of adherence: >50% adherence was achieved in 13 articles; moderate adherence was achieved in seven articles and adherence was unknown for four articles. See ►**Supplementary Table S3** (available in the online version) for the detailed study characteristics.

Associated Processes to Highlight Current Trends in the Field

We also considered the elements influencing adherence to connective health measures for CVD prevention. We used inductive thematic analysis, a qualitative analytical method,[34] to construct categories describing the content of the articles through dimensions preestablished dimensions. Two of the authors then reviewed six articles randomly and annotated each article with this set of categories. Based on the two sets of proposed annotations, we defined categories with their own sets of possible values, to determine the final characteristics for the annotation process. We extracted 10 characteristics from six articles[9,11,18,19,25,26] and identified variables with a colored mark if they applied to the article in question ►**Supplementary Table S4** (available in the online version) for the study characteristics. We focus here on the description of health interventions in cardiovascular risk prevention. We identified the main characteristics promoting adherence in connected health interventions designed to support cardiovascular prevention (►**Fig. 9**).

The 10 characteristics considered were connected health intervention (connect), adherence distribution, influence, randomized, survey (do), focus group (do), outcomes, data collection (direct or indirect), and others. Most studies covered a mean of five main characteristics, and none covered all the characteristics.

For instance, in three studies,[23,25,28] prevention activities were designed to induce changes in behavior. For reducing risk factors, placing messages in the context of the recipient's motivations was considered preferable to informational and prescriptive messages, for example, when trying to trigger changes in behavior.

Discussion

Interventional studies on CVDs have many technical characteristics in common and make use of economic methods derived from behavioral change techniques.[35] Applications are becoming ubiquitous in our everyday lives, and this aspect renders them particularly appealing as a tool in the domain of public health. They provide a low-cost means of disseminating health information "virally," potentially increasing the cost-effectiveness of health interventions.

They can also promote social support and social influence, facilitating changes in health behavior. In particular, network interventions that increase clustering warrant further investigations to determine their efficacy for inducing long-term changes in behavior.[32]

We evaluated the influence of connected health interventions on changes in health behavior-related outcomes. The connected health interventions considered had an overall positive effect on changes in behavior, which should encourage further research in this area. Further investigations are required to explore multiple aspects of preventive behavior, including concordance (negotiated agreement between the patient and the physician or another health care professional),[36] preference, satisfaction, and persistence.[37]

Another recent study,[39] on effective personalized prevention and e-health, aimed to develop computer-based tools rendering preventive approaches effective for both the physician and the patient, with a modular knowledge-based decision support system dedicated to cooperative decisions for preventing CVDs.

Research into the design and application of new, personalized digital connected health technologies integrating data concerning behavior and decisions can provide opportunities for the interventions to promote preventive health behavior. The use of mobile health to influence adherence with CVD prevention measures could be increased and improved. In the future, as increasing numbers of patients with chronic illnesses become users of connected health applications, studies of these applications are likely to focus increasingly on the self-management of chronic diseases. Future studies could also facilitate comparison of interventions through the development of standardized guidelines.[40]

Our study has several limitations and strengths. The small number of articles included reflects the current scarcity of studies in this emerging and rapidly evolving field. This lack of studies made it difficult to conduct analyses by health domain, type of intervention, and outcome. Indeed, variables such as education and work status were not generally included. Associated variables were not used at the same frequency and on the same population.

Ergonomic assessment, user perception, and the technical characteristics of the connected health interventions are therefore the key elements to be taken into account when trying to improve adherence results in a prevention program.

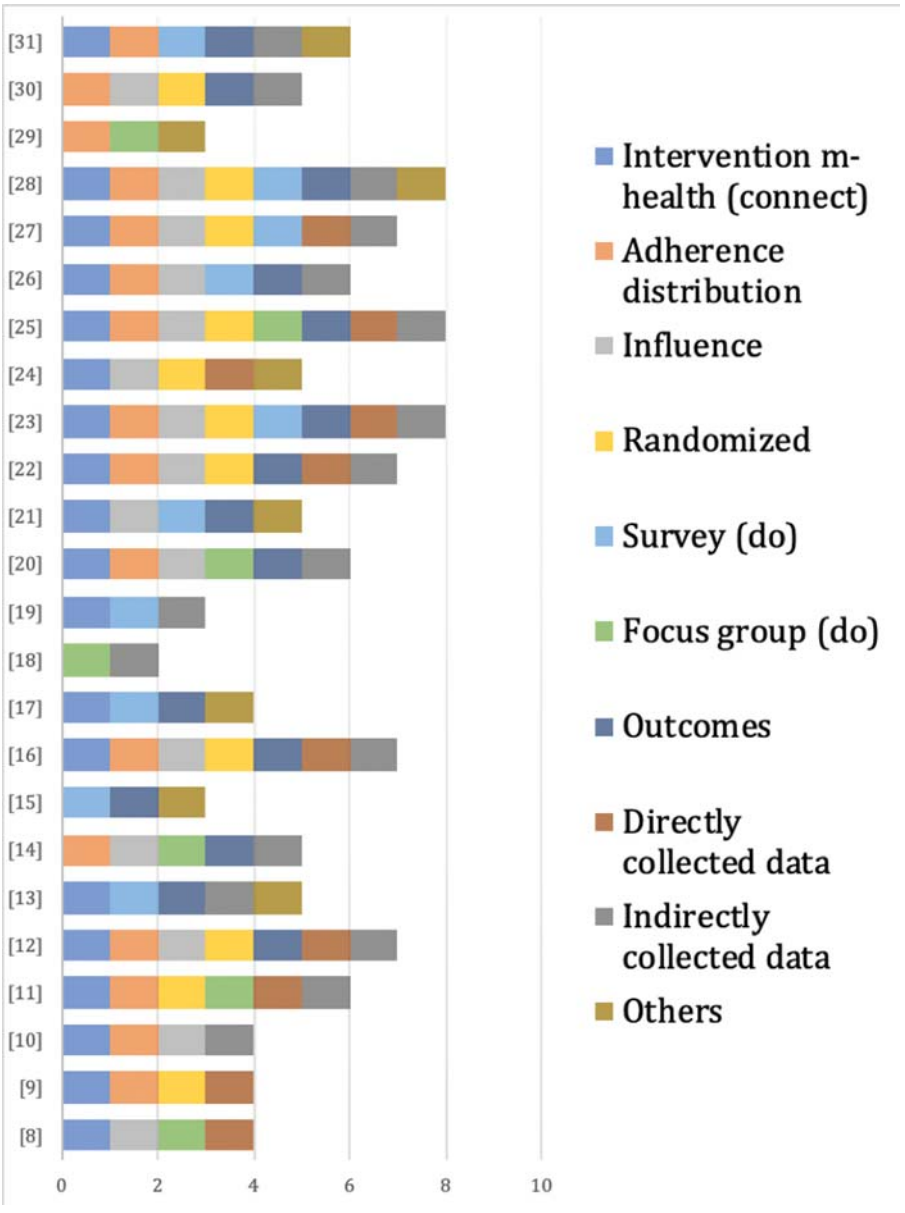

Fig. 9 Main characteristics of the interventions (identified with a colored mark if present).

Finally, the heterogeneity of the study designs included, and the lack of long-term results make it difficult to compare the interventions and the possible impact of techniques and principles on reported outcomes—potentially introducing bias.

This study also has several strengths. First, we followed a rigorous predefined, freely available protocol. Second, we performed an extensive literature search, with the help of an academic librarian, to ensure sensitivity and specificity. The studies covered a mean of five of the main characteristics, but none of the studies covered all characteristics. In all studies assessing the usability of connected health interventions and the users' acceptance of them, the apps concerned seemed to be well accepted and easy to use. Finally, as applications (connect) are now an integral part of our daily lives, they have a huge potential to improve engagement.

Conclusion

In conclusion, this scoping review provides an indication of current trends in the main characteristics of connected health interventions for CVD prevention. These findings improve our understanding of existing research in this field and will contribute to the development and evaluation of future connected health interventions and novel solutions. The results of this review support the view that research into connected health interventions for cardiovascular prevention remains in its infancy and that more studies are needed. The principal limitation of most existing connected health interventions is the difficulty evaluating user adherence and measuring the effectiveness of the intervention over time.

Clinical Relevance Statement

Studies including individual preferences are required to promote adherence and disease prevention through personalized recommendations. The prospect of being able to influence and support sustainable health behaviors maintaining the effective prevention of CVD should drive further research in this domain.

Multiple Choice Questions

This scoping review raises many questions that need to be addressed in future studies of connected health interventions such as:

1. What type of connected health intervention is most effective for improving adherence?

a. Nudge-SMS
b. Self-management applications
c. Survey
d. Focus group

Correct Answer: The correct answer is option b. Connected health interventions developed with the values and needs of users in mind may better motivate patients to achieve sustainable health behavior changes.

2. Does cardiovascular prevention with connected health interventions mostly target only one risk factors?

a. Yes
b. No

Correct Answer: The correct answer is option b. Most connected health interventions target multiple risk factors.

3. What are the most efficient actions of connected health interventions for users?

a. Read-connect
b. Do-connect
c. Read
d. Do

Correct Answer: The correct answer is option b. Do-connect actions are the most efficient for users.

4. How many dimensions were identified as criteria for inclusion?

a. Two
b. Three
c. Four
d. Five

Correct Answer: The correct answer is option b. We established inclusion criteria corresponding to three dimensions (cardiovascular risk factor, connected health interventions, and adherence distribution).

Authors' Contributions

All the authors contributed substantially to the design of the study and the acquisition, analysis, and/or interpretation of the data. The paper was drafted by the first author and critically reviewed by all the remaining authors. All the authors approved the final version.

Protection of Human and Animal Subjects

Not applicable.

Conflict of Interest

None declared.

Acknowledgments

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